Garfield++ simulation for wire plane optimization

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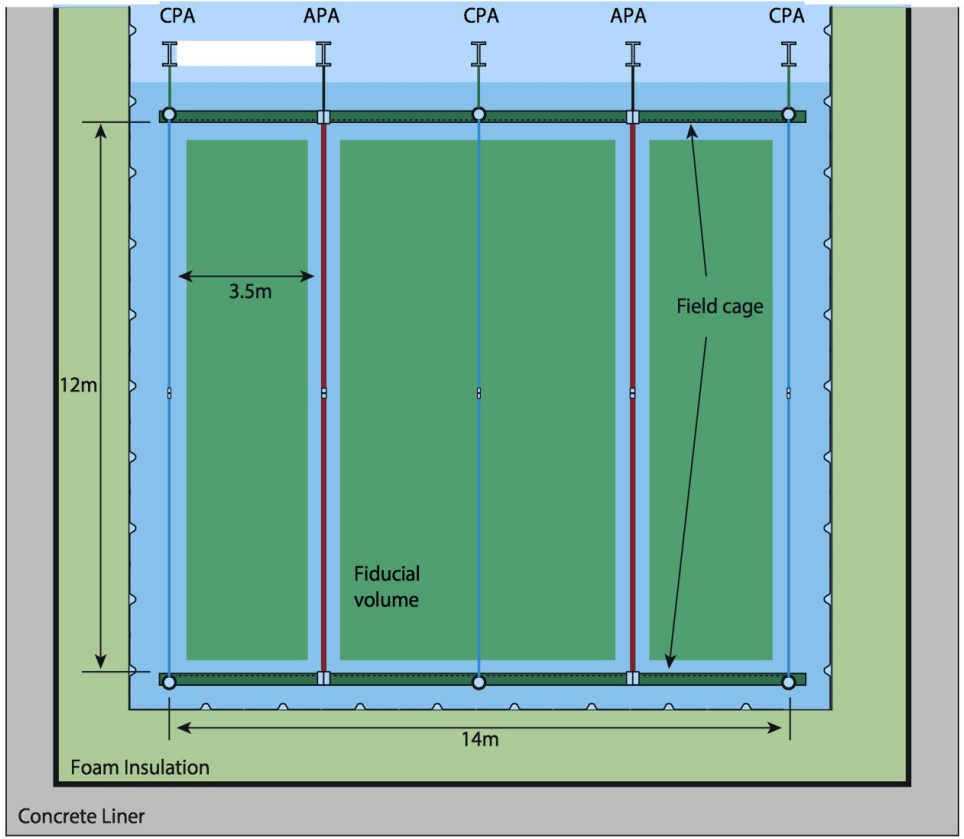
The big goal of this study:

- Use Garfield++ to simulate signal induced to the anode wires in the DUNE TPC.
- Test different wire configuration to help optimize the detector design.

Cross section of the 5-kt fiducial mass LBNE TPC inside the cryostat. The length of the TPC is 30 m along the direction of the neutrino beam:



- anode plane assemblies
- cathode plane assemblies
- field cage
- feedthroughs, filtering networks, cables and power supplies for the cathode high voltage system

APA description

- These four planes (along the direction of electron drift) are labeled as: the grid plane (G), the first induction plane (U), the second induction plane (V), and the collection plane (X). The wires on the grid and the collection planes are vertically oriented, while the two induction planes are oriented at ±35.71◦ to the vertical.
- resolution between wires : 4.7 mm
- distance between planes: 4.8 mm

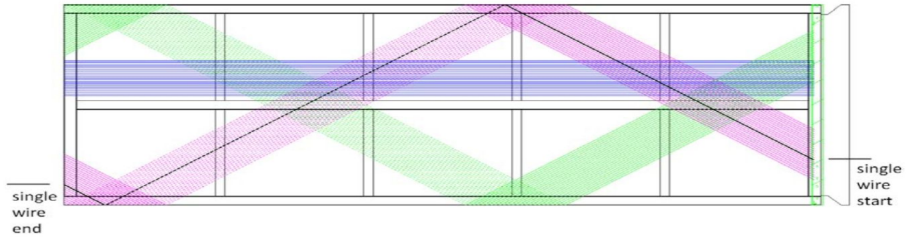


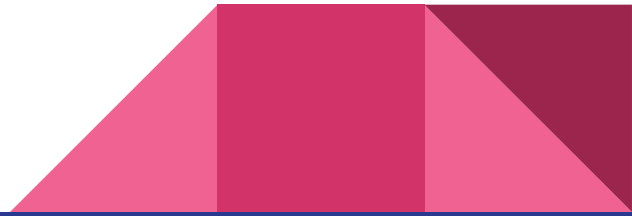
Figure 2.4: An illustration of a few wire paths on the APA. The length and width of the APA, and the wire angle, are chosen so that in the angled layers the wires wrap less than once around the APA. This can be seen from a single wire (shown in black in the magenta group) in the illustration. Small portions of the wires from the three signal planes are shown in color: magenta (U), green (V), blue (X). There is a fourth (G), un-shown wire plane above these three, and parallel with X, which is present to improve the pulse shape on the U plane signals.

Strategy:

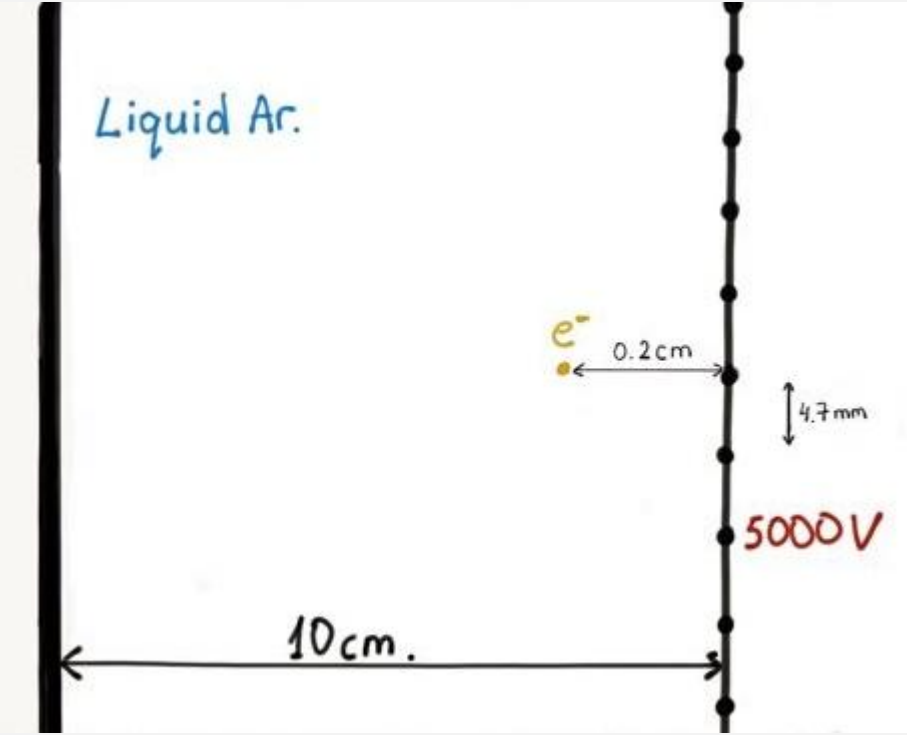
1) Use simplified geometry to check basic principle (done)

2) Simulate 2D geometry with multiple layers. (done)

3) Simulate 3D geometry with realistic wire angle for DUNE (in progress)

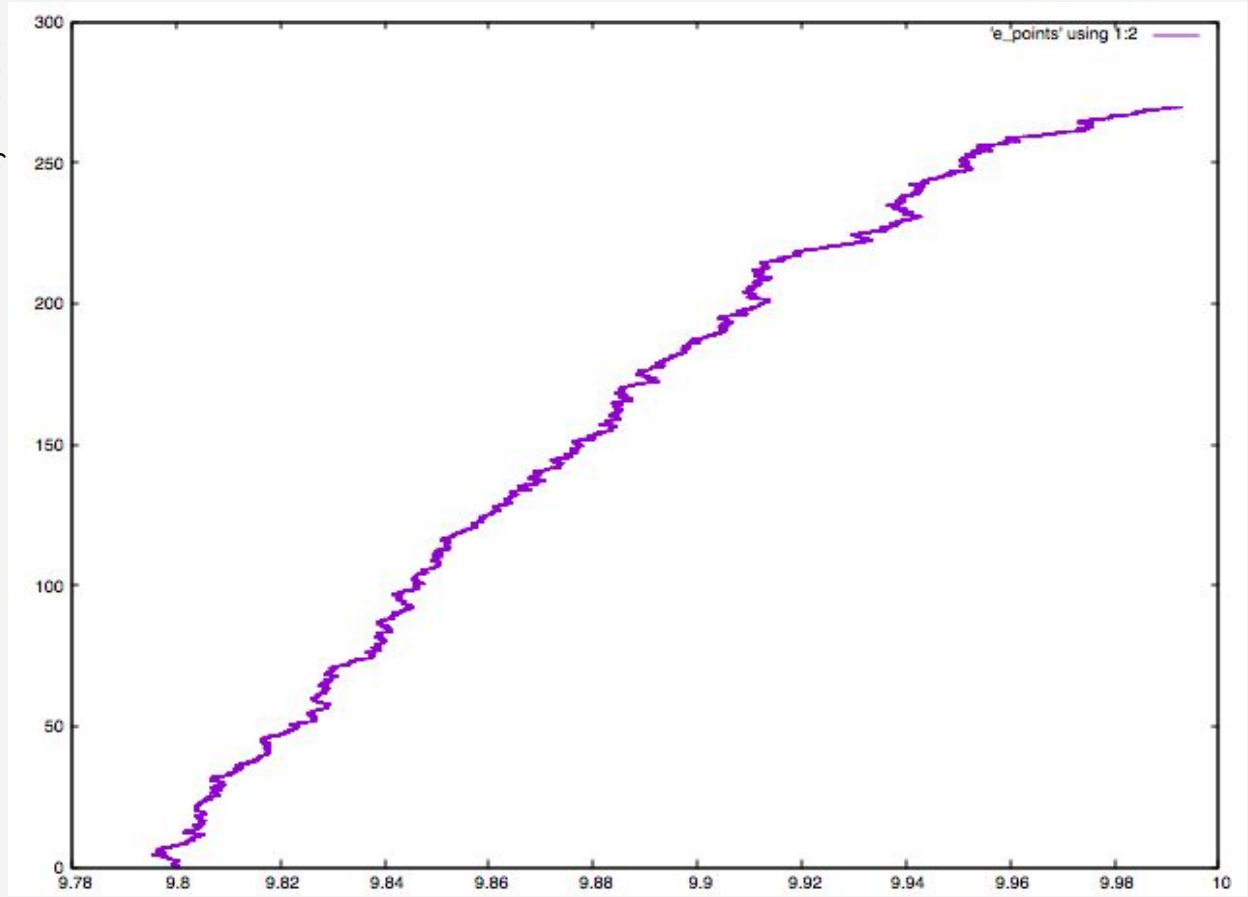


Simplified geometry



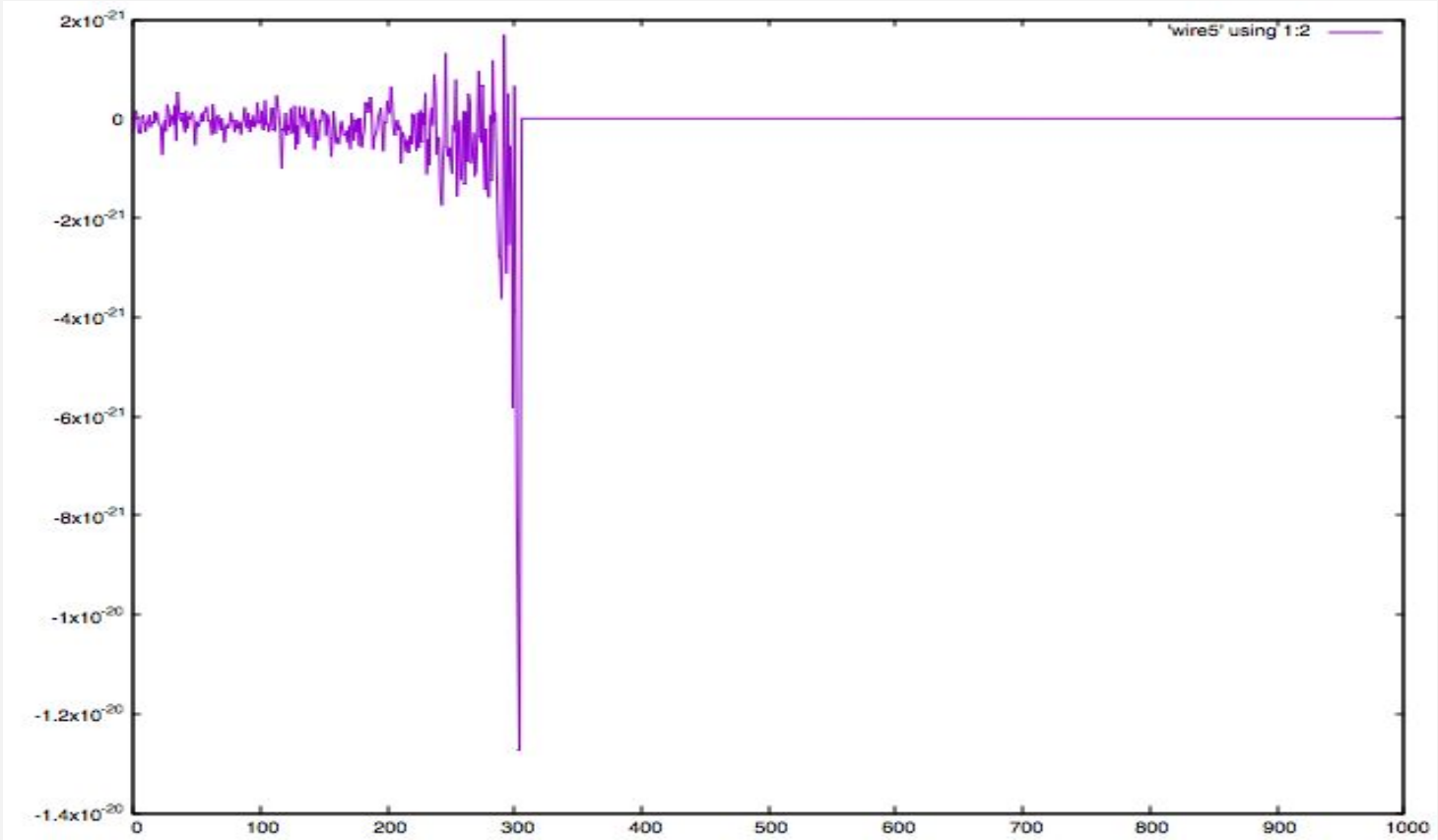
- a box full of liquid Ar
- 10 wires and a grounded plane inside the box
- each of the wires has 5000V
- the distance between the grounded plane and wires is 10 cm

Trajectory of the electron in liquid Ar before it

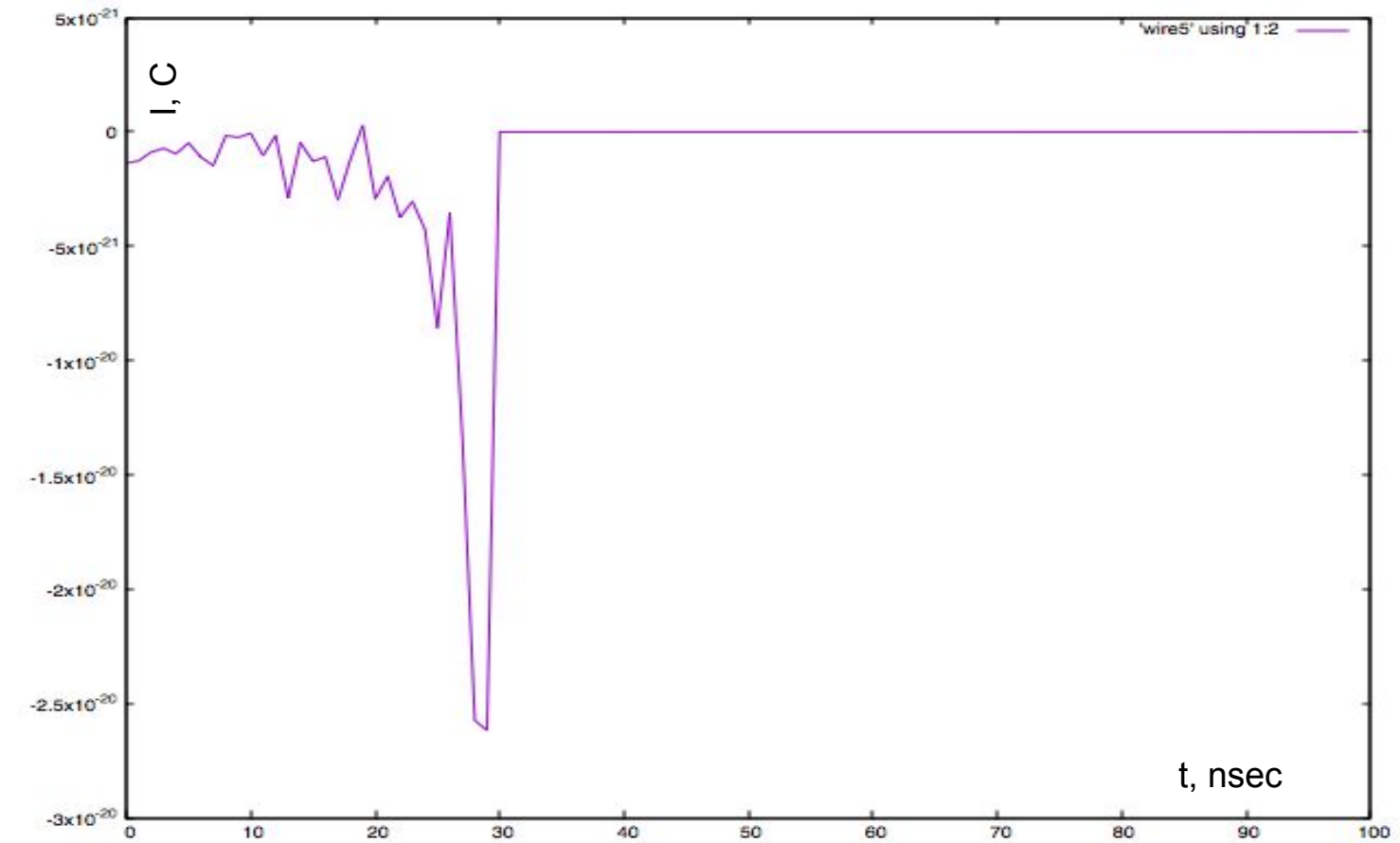


- arrangement of 10 wires
- tMax = 1000 nsec
- tStep = 1 nsec

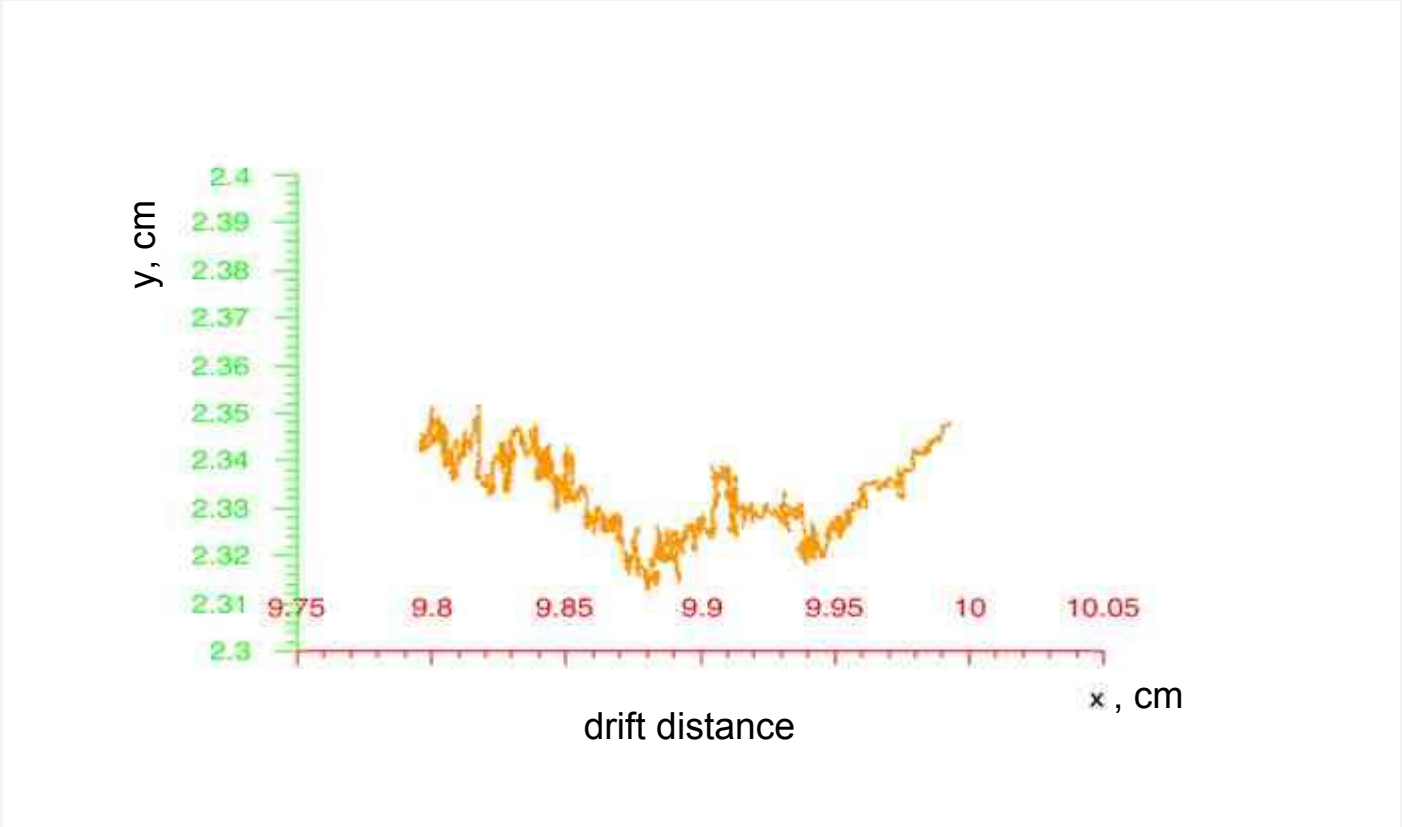
The signal gotten from a wire which was reached by the electron (tStep = 1 nsec)



The signal gotten from a wire which was reached by the electron (tStep = 10 nsec)



Trajectory of the electron in liquid Ar before it reaches a wire (tStep = 1)



Expectation:

Shockley-Ramo theorem:

$$\int I \cdot dt = e \cdot \frac{d}{D} = -1.6 \cdot 10^{-19} \cdot \frac{0.002}{0.1} = -3.2 \cdot 10^{-21}$$

Results:

- got constant result with “plane” setup: - 3.2 e-21
- signal induced to wire is different from ideal case due to non-uniform electric field, but got stable results at more than 100 wires

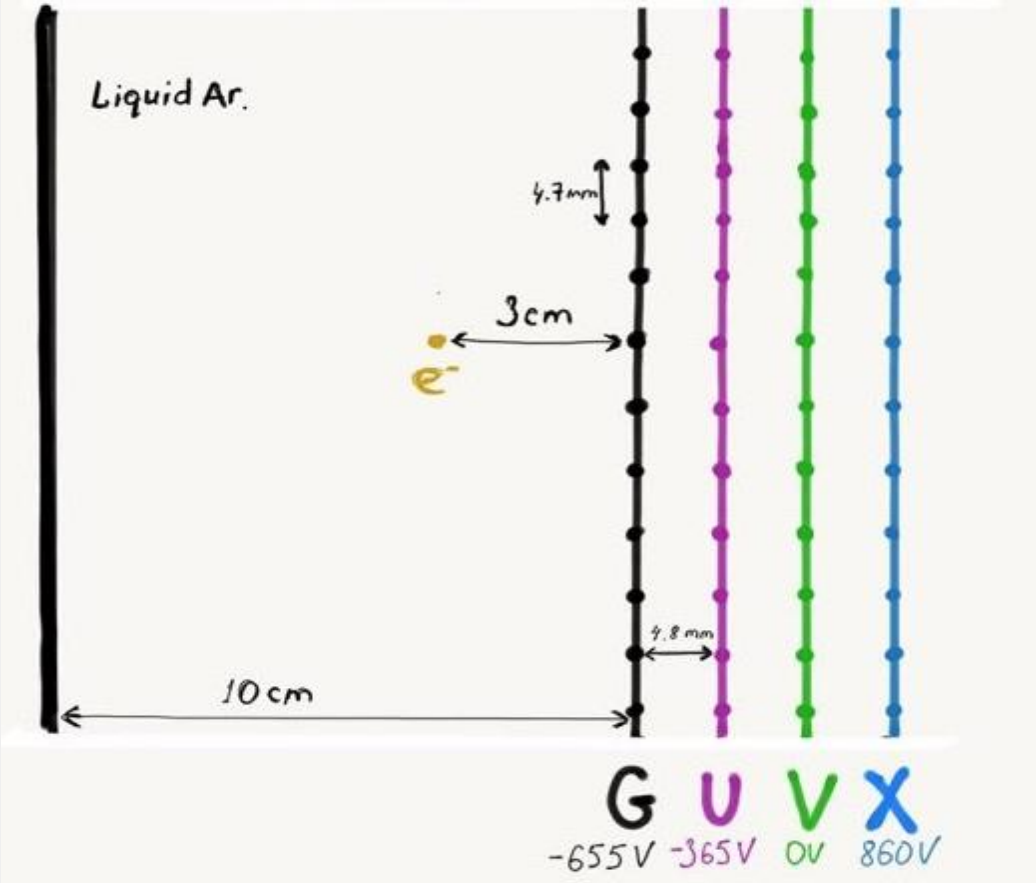
Simulation with multiple wire planes

- Simulate signal induced to each wire on each plane.

- Check how signal changes depending on wire configuration.

- Compared signal with different wire spacing: 3mm - 7 mm

Sketch of Current Setup (not to scale):

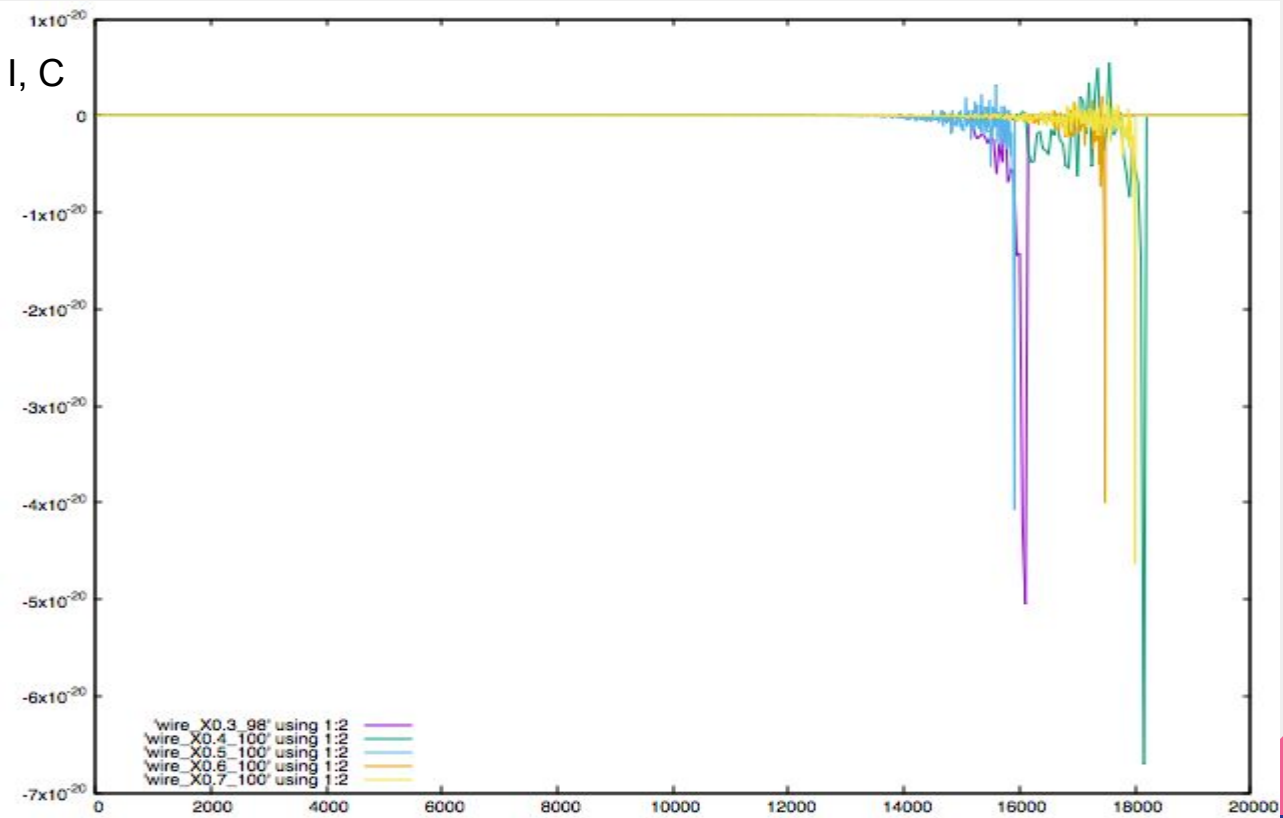


Four five planes with corresponding voltages:
Cathode plane: -700 V

The grid Plane (G): -655 V
The first induction plane (U): -365 V
the second induction plane (V): 0 V
the collection plane (X): 860 V

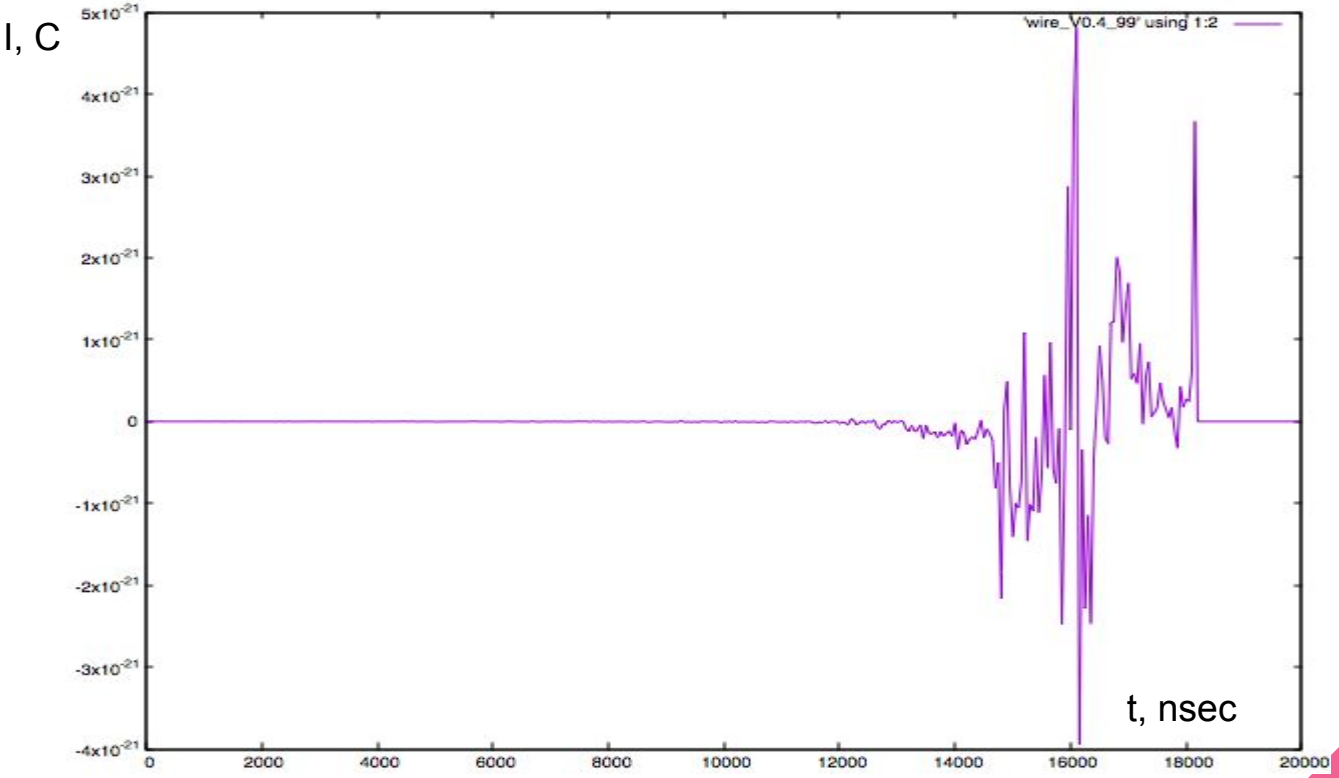
Default wire resolution: 4.7 mm
Default plane spacing: 4.8 mm

Signals for different wire resolution for X plane



Magenta: 3 mm
Green: 4 mm
Blue: 5 mm
Orange: 6 mm
Yellow: 7 mm

A Signal from a wire on V plane (3mm wire pitch)



Further expectations

- to finish 3D TPC model: to incline induction planes and see how the signal will change
- Run simulation with different parameters the same way as I done for this setup
- Change geometry parameters and analyze the difference of the signals.
- Provide inputs to event reconstruction